

Short communication. Paclobutrazol for height control of two *Lilium* L.A. hybrids grown in pots

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Abstract

Height control is often required in order to obtain bulb plants that are proportional to their pot size and to reduce post-harvest stem elongation. Plant growth regulators afford an effective means of controlling plant height. In this study, paclobutrazol (Pbz) was studied for use in the chemical dwarfing of potted *Lilium* plants —the hybrids ‘Ercolano’ and ‘Royal Respect’— for marketing. Their bulbs were dipped in the growth regulator (0, 50, 100, and 150 ppm) for 10 min before planting. Plant height (measured at 7 day intervals), the duration of the different stages of the growth cycle, the number of flower buds formed, and the number of open and aborted flowers were recorded. The average day and night air temperatures were 25 and 13°C, respectively. Increasing Pbz dose progressively reduced the height of the ‘Ercolano’ hybrid by between 29% (46.2 cm; 50 ppm) and 45% (35.3 cm; 150 ppm) compared to control plants (64.4 cm), however, neither the duration of flowering nor the number of flowers was modified. The ‘Royal Respect’ hybrid responded with a marked shortening – by 45% (20.8 cm; 50 ppm) to 59% (28.2 cm; 150 ppm) in comparison with the average control height (51.1 cm), but in this case both the duration of flowering and the number of open flowers was reduced at the highest concentration. The feasibility of cultivating these *Lilium* hybrids for marketing in pots is demonstrated. However, the concentration of paclobutrazol should be adjusted according to the hybrid grown.

Additional key words: bulb dips, chemical dwarfing, growth regulator, *Lilium* ‘Ercolano’ hybrid, *Lilium* ‘Royal Respect’ hybrid.

Resumen

Comunicación corta. Paclobutrazol para el control de la altura en dos híbridos de *Lilium* L.A. en producción de plantas en maceta

En la producción de bulbosas en maceta, a menudo se requiere el control de la altura para obtener plantas proporcionales al tamaño del contenedor y para reducir el elongamiento del tallo en pos-cosecha. Un medio efectivo de controlar la altura de las plantas es el uso de reguladores de crecimiento. Para proporcionar información sobre el enanizamiento químico en producción de plantas de *Lilium* en maceta, se estudió la efectividad del regulador de crecimiento paclobutrazol (0, 50, 100 y 150 ppm) en dos híbridos de *Lilium* L.A., ‘Ercolano’ y ‘Royal Respect’, aplicado por inmersión de bulbos durante 10 minutos. Se registró la altura a intervalos de 7 días, la duración de los diferentes estadios del ciclo y el número de flores formadas, abiertas y abortadas. Las temperaturas medias del aire (día/noche) fueron 25/13°C. El incremento de las dosis de paclobutrazol produjo un incremento en el control de la altura en el híbrido ‘Ercolano’ de 29% (46,2 cm) a 45% (35,3 cm) con respecto al testigo (64,4 cm), sin modificación en la duración de la floración ni en el número de flores. El híbrido ‘Royal Respect’ respondió al paclobutrazol con una marcada reducción de la altura, de 45% (20,8 cm) a 59% (28,2 cm), en comparación con el testigo (51,1 cm), pero en este caso, tanto la duración de la floración como el número de flores abiertas disminuyeron con la concentración más alta. Se demostró la viabilidad de cultivar los híbridos *Lilium* ‘Ercolano’ y ‘Royal Respect’ en macetas para su comercialización, y se confirmó que la concentración de paclobutrazol debe ajustarse para cada híbrido.

Palabras clave adicionales: enanizamiento químico, inmersión de bulbos, *Lilium* ‘Ercolano’, *Lilium* ‘Royal Respect’, regulador de crecimiento.

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Interest in producing potted *Lilium* spp. plants has recently emerged among cut flower producers due to the increase in the popularity—and hence the profitability—of these species as potted plants. Apart from their relative ease of cultivation, the value of potted *Lilium* spp. plants per unit greenhouse surface area is high (Miller *et al.*, 1998).

When producing bulb crops, height control is often required in order to obtain plants proportional to their pot size, to meet shipping requirements, and to reduce post-harvest stem elongation. An effective means of controlling plant height is to use plant growth regulators. Paclobutrazol (Pbz) {(+)-(R*,R*)-β-[(4-chlorophenyl)methyl]-α-(1,1-dimethylethyl)-1H-1,2,4-triazol-1-ethanol} is commonly used with bulb crops in today's floriculture industry (Krug, 2004). The pre-planting soaking of bulbs offers advantages over other application methods, such as time and labour savings, accuracy in dosage application, and its reasonable cost (Ranwala *et al.*, 2002). Many of the most vigorous lily cultivars traditionally grown for cut flowers can be raised in pots if growth regulators are used to obtain plants of a marketable size (Whipker and Hammer, 1993). Some authors suggest an acceptable height for *Lilium* in pots to be 30-40 cm (Krug, 2004), while others suggest 20-50 cm (Beattie and White, 1993). However, many cultivars can grow to 50 or even 60 cm in height (DeHertogh, 1996).

The use of Pbz to reduce plant height has already been tested in oriental hybrids by pre-planting bulb dipping for 30 min at concentrations of 100-200 ppm (Miller *et al.*, 1998; Dole and Wilkins, 1999). Ball and Miller (1996) demonstrated the effectiveness of this method with Pbz and other growth regulators (ancymidol and uniconazole) for the control of the height of *Lilium* L.A. hybrids. However, evidence has been found of a cultivar-dependent response, which emphasizes the need for appropriate dose adjustments (White, 1990; Ranwala *et al.*, 2002).

The aim of the present work was to determine the effectiveness of Pbz on the control of the growth of two popular L.A. hybrids of *Lilium* ('Ercolano' and 'Royal Respect'), by dipping their bulbs in solutions of this growth regulator before planting. The results show that by the use of appropriate doses of Pbz plants of marketable size can be obtained.

This experiment was performed at the INTA-San Pedro Agricultural Experimental Station (lat. 33°4'S, long. 59°4'W), Buenos Aires Province, Argentina, in the spring of 2005. The hybrids used were 'Ercolano' and 'Royal Respect'. Size 12/14 bulbs were planted

(one per pot) in 1L black polyethylene pots (diameter 12 cm), and grown in a metallic greenhouse with a polyethylene cover (25% ventilation) from September 6th. The bulb bases were placed at a soil depth of 8 cm. The substrate was a handmade mixture of 25% peatmoss (from the Epuyen region, Chubut, Argentina) + 75% soil (apparent density 0.8 kg m⁻³, porosity 2.2%, water retention 58.2%). The density of the pots on the greenhouse bench was 35 plants m⁻².

Water was provided by individual drip irrigation according to necessity (equal conditions for all treatments). The electrical conductivity of the irrigation water was 0.9 mS cm⁻¹. Once the shoots were 5-7 cm tall, a liquid fertilizer was applied at the rate of 200 ppm nitrogen and potassium (Smith, 2003).

To mimic the cultivation conditions of most local flower producers, the experiment was undertaken without greenhouse temperature control.

Paclobutrazol (commercial product Kultar SCTM, 25% active ingredient) was applied by dipping the clean bulbs in 1 L of 0 (water control), 50, 100 or 150 ppm solutions – concentrations chosen according to the BonziTM and SumagicTM pre-plant dip guidelines for a number of hybrid lily cultivars (Miller, 2003). The bulbs were placed in net bags (30 per treatment) and dipped in the treatment solutions for 10 min. These bags were then hung to drain, and the dry bulbs planted.

The experiment had a randomised complete block design with three replicates. Each experimental unit contained 10 plants. The analysis for each hybrid is presented separately.

Growth and development data are shown in Table 1.

Plants were inspected daily to check for damage and/or disease. The canopy air and substrate temperatures (5 cm depth) were averaged hourly; these data were stored using an ETG Multirecorder-P data logger.

The results were treated using the GLM and Mean procedures of the SAS statistical software package version 6 (SAS Institute, 1989). The Tukey test for non-additivity was used to confirm the normal distribution of the data, which were subjected to ANOVA ($\alpha=0.05$). The variables that did not show a normal distribution (days to emergence, height at all dates, and the number of open flowers) were transformed using the (x) square root procedure. For the variable «number of aborted flowers» the ($x+1$) square root transformation procedure was used. Treatments were compared using the Tukey test ($\alpha=0.05$), and the best linear, quadratic, or cubic fitting of the variables and the Pbz concentrations determined ($\alpha=0.05$).

Table 1. Definitions of *Lilium* hybrid growth and flowering variables

Variable	Description
<i>Growth stages after planting</i>	
Days to emergence	Emergence: visible appearance of the flower sprout
Days to visible flower buds	Tips of flower bud visible to the naked eye
Days to first open flower	Flower bud with separated tip petals
Days to the end of flowering	End of flowering defined as when the last open flower shows areas of minimum wilting at the petal edges
Duration of flowering	Time elapsed between the first open flower and the last wilted flower
<i>Plant height and number of flowers</i>	
Maximum height at 14, 21, 28, 35, 42, 49, 56, 63, and 70 days after planting	Maximum plant height reached by either the leaves or flowers without modifying their natural position
Number of flower buds	Number of flower buds completely formed
Length of the second flower bud	Length of the second flower bud when completely formed but still closed
Number of open flowers	Number of flowers showing maximum petal aperture
Number of aborted flower buds	Difference between the number of flower buds formed and the number of open flowers

At 28 days after planting, dose showed a significant quadratic relationship with height in both hybrids (Table 2). The maximum height reached before the opening of the first flower bud decreased with increasing paclobutrazol doses. 'Ercolano' responded to concen-

trations of 50, 100, and 150 ppm with a shortening of 29%, 33% and 45% respectively compared to the control treatment (64.4 cm). 'Royal Respect' responded to 50, 100 and 150 ppm with a shortening of 45%, 53% and 59% compared to the control (51.1 cm).

Table 2. Change in height (cm) of plants whose bulbs were treated with different paclobutrazol doses (0, 50, 100, 150 ppm) until the time prior to the first open flower

Paclobutrazol (ppm)	Days after planting								
	14	21	28	35	42	49	56	63	70
<i>'Ercolano'</i>									
0	1.6	2.6	16.4	26.8	34.5	42.9	49.9	58.2	64.4
50	1.5	2.3	9.8	14.4	18.7	24.7	31.1	39.2	46.2
100	1.5	2.4	10.5	14.1	17.7	22.4	28.1	36.5	42.7
150	1.2	2.4	9.4	12.1	14.2	17.5	22.3	29.6	35.3
CV ¹	21.7	11.8	8.9	7.9	8.2	8.1	7.8	7.2	6.9
Pr>F ²	—	—	C<0.0001	C<0.0001	C<0.0001	C<0.0001	C<0.0001	C<0.0001	C=0.0011
<i>'Royal Respect'</i>									
0	4.6	9.2	14.8	20.4	25.4	31.6	37.5	44.3	51.1
50	4.1	7.2	8.5	9.5	10.3	12.6	16.1	22.7	28.2
100	4.2	6.6	7.6	8.3	8.4	9.8	12.5	18.3	24.0
150	3.7	6.7	7.3	7.9	7.6	8.5	10.8	15.5	20.8
CV ¹	10.8	6.3	8.1	7.1	7.9	7.8	7.2	7.2	6.8
Pr>F ²	L=0.0011	Q<0.0001	C=0.0005	C<0.0001	C<0.0001	C<0.0001	C<0.0001	C<0.0001	C<0.0001

¹ CV: coefficient of variation. ² Probability >F of significant trends (5%). L: linear. Q: quadratic. C: cubic.

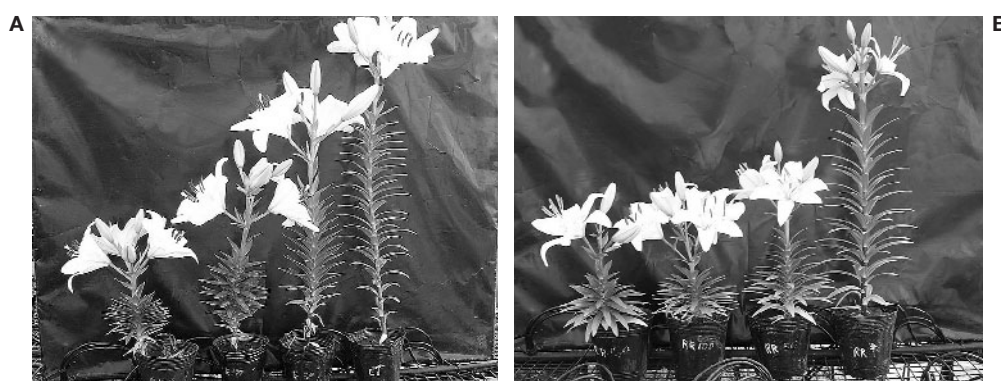


Figure 1. Differential responses by *Lilium* hybrids 'Ercolano' (A) and 'Royal Respect' (B) to paclobutrazol. From left to right: appearance of plants at the stage of full flowering after bulb soaking in 150, 100, 50 and 0 ppm paclobutrazol respectively for 10 min.

For both hybrids, the maximum height attained after dipping in the assayed Pbz doses was in the range of 20-50 cm (Table 2), an appropriate height for marketing plants well proportioned to their pots (Beattie and White, 1993). However, the varietal response was different; 'Royal Respect' plants were restricted to a height lower than 30 cm even with the lowest dose (50 ppm) of Pbz (Fig. 1).

Ball and Miller (1996) reported a stronger effect of Pbz on the *Lilium* L.A. hybrid 'Royal Fantasy'; 10 min dips reduced the height at flowering by 53% at 100 ppm and 66% at 150 ppm. These authors reported a day temperature similar to that of the present study (24°C), and a higher night temperature (17°C) (Table 3). Moore (1979) suggested a strong interaction between the temperature difference between day and night (DIF) and the endogenous levels of gibberellic acid to explain why the effect of another plant growth regulator, ancymidol, on stem elongation diminished as DIF increased. Temperate night temperatures (16°C) reduced stem length in comparison with colder night tempera-

tures (10°C) in the cultivars 'Enchantment', 'Sterling Star', 'White American' and 'Uchida' (Marlogio *et al.*, 1987). In the present study, the night temperatures were below 13.1°C from planting until the first flower bud with colour appeared (sale time), and the DIF varied between 12 and 13°C depending on the plant cultivation stage. Future assays should determine whether variations in DIF affect the responses of 'Ercolano' and 'Royal Respect' to Pbz.

In 'Ercolano', effects of treatments on different stages of cultivation and even on the characteristics of flowering were not observed, except a slightly earlier visible appearance of flower buds (less than 0.3 day) between anyone of the Pbz doses and the control (Table 4).

In 'Ercolano', Pbz (at any dose) appeared to have no effect on the time to reach the different growth stages or on the characteristics of flowering [except for a slightly earlier appearance of the flower buds (difference <0.3 days)] (Table 4). In 'Royal Respect', however, slight treatment effects were observed on emergence

Table 3. Average air and substrate temperatures recorded at different cultivation stages

Cultivation period	'Ercolano'			'Royal Respect'		
	Average temperature (°C)			Average temperature (°C)		
	Substrate	Air night	Air day	Substrate	Air night	Air day
Planting - emergence	14.5	8.6	20.5	14.9	9.1	20.9
Planting - visible appearance of inflorescence	16.9	10.9	22.8	16.9	10.9	22.8
Planting - 1 st coloured flower bud	18.7	13.0	24.8	18.8	13.1	24.9
Planting - end of flowering	19.4	13.7	25.5	19.5	13.8	25.6
First coloured flower bud - end of flowering	26.0	20.3	32.2	26.2	20.6	32.2
Average: planting - end of flowering	19.1	13.3	25.2	19.3	13.5	25.3

Table 4. Comparison of variables related to the duration of the different *Lilium* growth stages and characteristics of flowering in plants raised from bulbs treated with the different concentrations of paclobutrazol (0, 50, 100, 150 ppm)

Paclobutrazol (ppm)	Days until emergence	Days until visible flower bud tips	Days to first open flower	Days to ending of flowering	Duration of flowering	Number of flower buds	Number of open flower formed	Number of aborted flower buds
<i>'Ercolano'</i>								
0	9.6	36.2	75.2	83.1	7.8	5.5	5.3	0.21
50	10.0	36.1	75.6	83.1	7.5	5.6	5.4	0.17
100	9.7	35.9	75.4	83.1	7.7	5.8	5.6	0.17
150	10.5	36.0	76.0	83.1	7.1	5.6	5.3	0.14
CV ¹	10.6	1.2	1.5	0.5	15.3	16.9	10.9	18.1
Pr > F ²	—	L = 0.0400	—	—	—	—	—	—
<i>'Royal Respect'</i>								
0	5.7	36.9	76.3	84.4	8.2	5.4	5.1	0.36
50	5.9	36.0	76.3	84.5	8.1	5.4	5.0	0.32
100	5.9	35.5	76.7	84.7	8.0	5.8	5.6	0.17
150	6.3	36.0	77.3	84.2	7.0	4.7	4.4	0.24
CV ¹	9.1	3.6	1.1	0.96	14.1	21.5	12.2	19.2
Pr > F ²	L = 0.0421	Q = 0.0067	L < 0.0001	—	Q = 0.0078	—	C = 0.00042	—

¹ CV: coefficient of variation. ² Probability > F of significant trend (5%). L: linear. Q: quadratic. C: cubic.

(lag), the appearance of the inflorescence (advanced), and the number of days to the first open flower (Table 4). Although significant, these effects cannot be considered of commercial importance.

Working with 'Royal Fantasy', Ball and Miller (1996) observed a lag time of 2 and 3 days in flowering after 10 min bulb dips in Pbz at 100 and 200 ppm respectively. In 'Royal Respect', the duration of flowering was slightly reduced in plants thus treated with doses of 50 and 100 ppm, but by more than 1 day in those treated with a 150 ppm dose. In this hybrid a detrimental effect on the number of open flowers was also observed with the 150 ppm dose (Table 4).

For the Asiatic cultivars 'Enchantment' and 'Lemon-glow', ancymidol has been reported to have similar effects on flowering variables; following a brief bulb dip treatment (5 s) with 16.5 ppm ancymidol, a minimum lag time in flower opening was seen although the number of flower buds was not affected (Adzima, 1986).

Under the spring greenhouse climatic conditions of the north of the Buenos Aires Province, Argentina (average night/day air temperatures 13/25°C), potted 'Royal Respect' and 'Ercolano' *Lilium* hybrids of commercially acceptable height can be obtained by immersing their bulbs in Pbz for 10 min before planting. However, the concentration of paclobutrazol should be adjusted according to the hybrid grown.

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